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ure for the promotion of learning in America has ever been proposed.

I have the honor to remain,

Yours, with the highest respect,

CHARLES S. MINOT,
Chairman.
President A. A. A. S.

Harvard Medical School,
Boston, Mass.

Replies, in every case favorable, have been received from the following institutions:

Woman's College of Baltimore.
University of Buffalo.
Case School of Applied Science.
University of Colorado.
Columbian University, Washington.
Hamilton College.
Knox College, Galesburg, Ohio.
Massachusetts Institute of Technology.
Michigan College of Mines.
University of Minnesota.
University of Nebraska.
New York University.
College of the City of New York.
Northwestern University.
Oberlin College.
University of Syracuse.
Tufts College, Boston.
Vassar College.
Wellesley College.
Wesleyan University.
Western Reserve University.
Williams College.

The action has not been uniform, for in a few institutions no change in the vacation was necessary, but several institutions have changed the dates of their vacation to allow the necessary time for Convocation Week to become free. A small minority of the institutions have voted to allow their teachers leave of absence to attend meetings during Convocation Week. Almost every reply has included an expression of cordial approval of the plan.

The Committee hopes to continue and extend its correspondence with those universities and colleges which have not yet taken action, and to be able later to report their adhesion.

The facts above reported seem to the Committee to justify the expectation that the proposed Convocation Week will be permanently established through its formal acceptance by all the leading higher educational institutions of the country.

CHARLES S. MINOT, *Chairman*,
R. S. WOODWARD,
E. L. NICHOLS,
L. O. HOWARD,
J. McK. CATTELL.

A CENTURY OF PROGRESS IN ACOUSTICS.

IN selecting the 'Progress of Acoustics,' on its experimental side, as the subject for this year's presidential address, I am fully alive to the fact that this branch of science has been comparatively neglected by physicists for many years, and that consequently I cannot hope to arouse the interest which the choice of a more popular subject might command. It is, however, just because of this neglect of an important field of science that I conceive it to be my duty to direct some attention thereto. This duty I can best perform, it seems to me, by taking a survey of the work accomplished in this particular field during the century that has just closed. Such a survey will make it evident not only that the science of acoustics has made immense progress during that time, but also that many of the experimental methods in use in other branches of physical science were invented and first employed in the course of acoustical research. This latter fact, though not generally recognized, furnishes an illustration of the interdependence which exists between the various branches of physical science, and suggests the probability that the work of acoustical research in the future may be advanced by experimental methods specially designed for investigation in other fields. A revival will, of course, come in time for acoustics, as it has recently come for electricity, and it ought to come all the

sooner because of the cooperation which physicists may naturally look for from those who are cultivating the new fields of experimental psychology.

In order to avoid the tedium of a bare enumeration of discoveries arranged chronologically, I propose to refer in the first instance to the invention of the various experimental methods which have been employed in acoustical research. A separate reference to these methods will enable us to appreciate their potency in the advancement of this science.

The earliest of these methods is due to Chladni, whose work, 'Die Akustik,' appeared in the form of a French translation in 1809, under the title 'Traité d'Acoustique de Chladni.' In this work were collected all the researches on the vibrations of bodies which Chladni had conducted with the aid of the new method (méthode de sable). This method consists in distinguishing, on the surfaces of vibrating bodies, the parts which are vibrating from the parts which are in repose, by means of the sand which is driven from the former to collect on the latter. In these experiments of Chladni on plates, etc., the violin bow was used for the first time to produce the necessary vibrations. The bow had previously been used only for vibrating cords, the 'violon de fer,' and other musical instruments. Chladni made his discovery of sand figures in 1787, having been led thereto by Lichtenberg's discovery of electric figures.

The transversal nodal lines given by Chladni's method in the case of rods vibrating longitudinally were readily explained. Not so, however, the complicated nodal lines presented by vibrating plates, or the alternate lines which appear on the two sides of rods vibrating longitudinally, and which sometimes also appear on rods vibrating transversally. It was not until 1833 that an explanation of the former of these phenomena was offered by Wheatstone's theory that the nodal lines were due to the superposition of transversal vibrations, corresponding to sounds of the same pitch coexisting with respect to different directions in the plate. This theory was confirmed experimentally in 1864 by Rudolph Koenig, who constructed rectangular plates giving unison notes corresponding to different sets of nodal lines parallel to two adjacent sides of the plate. The theoretical figure results when the plate is vibrated so as to produce the coexisting unison notes.

The alternate nodal lines given by vibrating rods were also explained by the theory of the coexistence of two sounds near unison in the same vibrating rod. In this case, however, one sound corresponds to longitudinal, and the other to transversal vibrations. This explanation was first given by Augusta Seebeck in 1849, whose theory was confirmed in 1859 by Terquem in a very important paper 'Sur les vibrations longitudinales des verges libres aux deux extrémités.'

In 1807, five years after the publication of Chladni's 'Akustik,' appeared Dr. Thomas Young's 'Course of Lectures on Natural Philosophy and the Mechanical Arts' in which we find the earliest description of the graphical method, including its application to chronography. This description is as follows:

"By means of this instrument we may measure, without difficulty, the frequency of the vibrations of sounding bodies, by connecting them with a point which will describe an undulated path on the roller. These vibrations may also serve in a very simple manner for the measurement of the minutest intervals of time; for if a body, of which the vibrations are of a certain degree of frequency, be caused to vibrate during the revolution of an axis, and to mark its vibrations on a roller, the traces will serve as a correct index of the time occupied by any part of the revolution, and the motion

of any other body may be very accurately compared with the number of alterations marked, in the same time, by the vibrating body.'' Notwithstanding the clearness of this description, the graphical method remained for a long time unknown, and when it was developed later, in 1862, the original discovery was incorrectly attributed to Wilhelm Weber (1830). Between these dates slight applications of the method had been made by Savart, Duhamel, Lissajous and Desains, Wertheim, and others; the most important of such applications being that of Scott, who in 1858 applied it to his phonautograph. Finally, from 1858 to 1862, Rudolph Koenig devoted himself specially to the perfecting of this method, and exhibited the results of his labors at the Exhibition in London in 1862, in the form of a large collection of phonograms. This collection in its seven sections comprises all the applications of the method which have so far been made in acoustics. Whilst the progress of this method was thus slow before 1862, its use from that time onward became general, especially in physiological researches, in connection with which it received its widest development in the publication by M. Marey of his splendid work, 'La méthode graphique' in 1878. Parenthetically I might remark that Edison's phonograph (1877) was doubtless suggested by Scott's phonautograph.

As with the graphical method, the earliest suggestion of an optical method of studying vibratory movements came from Dr. Thomas Young, who in 1807 gave the construction of curves resulting from the composition of two rectangular vibratory movements. The practical realization of these curves was effected in 1827 by Wheatstone in his kaleidophone. The most important advance, however, in the development of this method was made by Lissajous, who, after some preliminary work in 1855, published in 1857 his great paper entitled 'Mémoire sur l'étude optique des movements vibratoires.' The optical effects produced by Lissajous' method, especially when the curves were projected on the screen, were so beautiful that the method obtained general recognition, and became immediately popularized. The chief merit of the method, however, does not lie in the beauty of the effects thus obtained, but rather in the fact that by this means we are enabled to determine with facility and with the utmost accuracy both the interval and the difference of phase between two vibratory movements. It is this fact which renders the optical comparator one of the most important instruments at the disposal of the acoustician.

A second optical method we owe to Biot, who in 1820 showed that the changes in density at the nodes of a transparent body vibrating longitudinally could be exhibited when the nodal line of the body is placed between the crossed mirrors of a polarization apparatus. During the continuance of the vibrations the image is highly illuminated in the analyser and becomes darkened when the vibrations stop. This method was developed much further by Kundt in 1864, and by Mach in 1873.

A third optical method was devised by Toepler and Boltzmann in 1870 for the purpose of exhibiting the changes which take place at a nodal point of a vibrating column of air. This method consists in producing interference bands by means of two rays of intermittent light from the same source, one of which passes through the air in its normal state, and the other through a nodal point of the vibrating air column. A vibratory movement of the interference bands results—a movement which can be made as slow as we please, thus rendering it possible to deduce by stroboscopic methods exact measurements as to the movement of the air at the nodal point.

The object of the method of manometric

flames, invented by Rudolph Koenig in 1862, is to furnish an ocular proof of the variations in density at a point of the air traversed by waves originating in another body or in the air itself. A short description of the first apparatus based on this method appeared in Poggendorff's *Annalen* in 1864. Between that year and 1872 the method was applied to a series of instruments, the experiments being described in the same journal in a long memoir entitled, 'Les flammes manométriques.' Although this method is extremely sensitive and capable of furnishing very accurate results, it has been prevented for a long time from rendering more efficient service on account of two causes: first, the want of sufficient brightness in the reflected images of the jumping flames, and second, the difficulty of observing the details of these images owing to their momentary appearance in the mirror. The former of these difficulties has now been overcome by the employment of acetylene and other gases, which at the same time allow admirable photographs of the flames to be taken, thus obviating the second difficulty also. We owe an important paper on this subject to Professors E. L. Nichols and Ernest Merritt published in 1898 in the *Physical Review*.

In 1865, Kundt published his method of using light powders for the purpose of exhibiting the vibratory character of stationary air waves in columns and plates of air. During the existence of these vibrations the light powders arrange themselves in transversal striæ which collect around the loops, and are wanting at the nodes. As in the case of the nodal lines on Chladni's plates, a satisfactory explanation of these striæ was for a long time wanting. In 1890 Professor Walter Koenig showed, from hydrodynamical considerations, that the particles of the powder necessarily arrange themselves in planes at right angles to the direction of the vibratory movements, and that their observed distribution at the loops and nodes is in accordance with the same laws.

Before the invention of the preceding methods the acoustician occasionally resorted to the device of deducing the vibrations of a sounding body from the behavior of a similar body whose movements were of sufficient amplitude to be seen by the eye, and so slow that they could be readily counted. In this way Mersenne counted the vibrations of a cord 15 feet long under a stretching force of 7 pounds, and found them to be 10 per second. In shortening the cord to $\frac{1}{20}$ of its length, he obtained an audible sound whose pitch, he concluded, corresponded to 200 vibrations per second. In the same way Chladni employed a long and thin metal rod, which gave in the first instance only 4 vibrations per second. He then shortened the rod until it gave an audible sound whose pitch he determined from the law expressing the relation between the length and the number of vibrations. This method, however, which appears so simple in theory, is subject to large errors and gives in practice very poor results.

Mersenne's and Chladni's method has accordingly given place to another—the stroboscopic—which allows the vibrations of the sounding body to be viewed directly, its movements relatively to a vibrating eyepiece being rendered as slow as we please. The first use of stroboscopic discs for the purpose of observing very rapid periodic movements was made by Plateau in 1836. His discovery, however, remained unnoticed, for Doppler, in 1845, published a note on the same subject, without referring to Plateau's discovery. It was Toepler who first made the method generally known by employing it in a series of acoustical experiments which he published in Poggendorff's *Annalen*, Volume 128. In the earlier applications of this method, the view of the vibrating body was rendered intermittent by looking through slits which were opened

and closed in rapid succession. This plan was modified by Mach who caused the vibrating body to be illuminated by intermittent light.

If now we allow the stroboscopic images of a moving body to fall on a photographic plate, giving the plate a movement of translation which is arrested before each appearance of the image, we thereby obtain a series of photographs of the successive positions assumed by the body. If, further, matters are so arranged that the beginning and duration of the phenomenon are traced on the images, we have a new method, which is called chronophotography. It was M. Janssen who first conceived the idea of taking automatically a series of photographic images in order to determine the successive positions at different times of the planet Venus in its passage across the sun. It was Janssen also who, in 1876, first suggested the idea of applying successive photograms to the study of animal locomotion. The analyzing of such movements was first accomplished by Muybridge, of San Francisco. The method has been largely extended and perfected by M. Marey, who has employed it in studying the locomotion of all sorts of subjects, from men to insects.

The last of the methods to be noticed is that employed by Rudolph Koenig in his wave-siren. In this instrument a metal band or disc with curvilineal edges passes before a narrow slit from which issues a current of compressed air. By means of these discs we can produce either simple sounds, or sounds of various timbres, containing such harmonics as we please, the intensities and phases of the latter being varied at will. The first wave-siren was constructed in 1867, and the account of the first series of experiments was published in 1881.

The mere enumeration of the methods of acoustical research which have been devised since the days of Chladni is an indication of the enormous advances which have been made in this branch of science. It remains now to state more particularly what these additions to our knowledge of acoustical phenomena have been. This can be most conveniently done under the following heads, viz.: The velocity of sound; its pitch, intensity and timbre; and the phenomena produced by the coexistence of two or more sounds.

THE VELOCITY OF SOUND.

Long before the beginning of the last century it had been observed that the propagation of sound was not instantaneous. Mersenne in fact had tried to estimate the velocity by experiments on echoes, and by counting the time which elapses between the flash of a gun and the report. The latter experiments were also repeated by Kircher as well as by the Academy of Florence in 1660. The same experiments were subsequently, in 1738, undertaken by members of the Academy of Sciences at Paris, by savants, such as Kaestner, Benzenberg, Goldingham and others, but the results obtained did not gain the confidence of the scientific world. A new series of experiments was accordingly undertaken in 1822, on the suggestion of Laplace, by members of the Bureau des Longitudes, to determine the velocity in air and other media. These experiments, which were the beginning of truly scientific work in this subject, were performed by Prony, Arago, Mathieu, A. de Humboldt, Gay-Lussac and Bouvard, between Montlhéry and Villejuif, cannon being fired at both stations. The result obtained was 331 m. at zero temperature, with an increase of 0.6 m. for each degree above zero. In the course of these experiments it was observed that the cannon fired at Villejuif were all distinctly heard at Montlhéry, whilst the reciprocal reports were so faint that only a

small number were heard. Tyndall long afterwards, in 1875, explained this curious phenomenon, attributing it to the existence at Villejuif of a heterogeneous atmosphere, caused by the heated air which came from Paris.

Since the memorable experiments of the Bureau des Longitudes of Paris, various individuals have from time to time undertaken to solve the same problem. Among these may be mentioned Moll and van Beck (at Utrecht), Gregory Woolwich, Stone and Captain Perry in his voyages to the polar regions in 1822, 1824, and Kendall in the Franklin expedition in 1825. In some of these experiments the temperatures ranged from 2° to — 40°, the results obtained according with the theoretical values. In 1823 Stampfer and Myrback conducted experiments between two stations in the Tyrol at a difference of level of 1,364 m.; a similar experiment being undertaken in 1844 in Switzerland by Bravais and Martin with a difference of level of 2,079 m. Both experiments confirmed the law that the velocity of sound in air is independent of the pressure.

In all these experiments the exactness of the results was affected by the difficulty of estimating accurately the time between the perception of the flash and that of the report. Different observers of course gave different estimates. This source of error was first eliminated by Victor Regnault, who in his long series of researches between 1860 and 1870 made use of the graphical method and electric signals to measure time intervals. Regnault's experiments were conducted in seven tubes (part of the Paris sewers) varying in length from 70 m. to 4,900 m., and of diameters from 0.11 m. to 1.10 m. Experiments were also conducted in the open air by means of reciprocal shots fired from two stations at a distance of 2,445 meters. The number of shots fired was 334. These researches of Regnault represent such an enormous amount of work that I shall attempt to give only the principal conclusions deducible from them:

1. In a cylindrical tube the intensity of the wave varies, diminishing with the distance. The narrower the tube, the more rapid is the diminution.

2. The velocity of the sound decreases as the intensity diminishes.

3. The velocity approaches a limiting value, which is higher, the greater the diameter of the tube. The mean value in dry air at 0° in a tube of diameter 1.10 m. is 330.6 m.

4. The velocity is not affected by the mode of producing the sound wave.

5. The velocity in a gas is independent of the pressure.

6. The ratio of the velocities in air and any other gas is $\sqrt{\frac{1}{\partial}}$, where ∂ is the density of the gas, supposed perfect.

7. The average of the results of all the experiments in the open air is 330.7 m. at 0°.

Regnault was also the first to attempt direct experiments for determining the velocity of musical sounds. In this case, however, the electric signals and the graphical recording apparatus were not sensitive enough to respond to the front of the wave, and it became necessary to resort to the ear alone. In these experiments Regnault had the cooperation of Koenig as observer, with whose assistance it was shown that:

1. A note does not change sensibly when it traverses long distances in tubes of large diameter.

2. When the sounds are observed by the ear the velocity of high notes appears to be less than that of low ones. This may be due to the more ready response which the tympanum makes in the case of low notes.

3. In traversing tubes of great length, a

note does not preserve its timbre, being resolved into simple components.

Regnault's experiments have recently been repeated by M. Violle in the large sewers near Grenoble and Argenteuil, some of Regnault's apparatus being employed for the purpose. The results of these experiments have not, however, been yet published.

PITCH.

Before the last century, as already mentioned, Mersenne had attempted to determine the vibrations of a cord by deducing them from very slow vibrations of the same cord when lengthened. Cheadni's tonometer, which consisted of a vibrating metal rod of variable length, was based on the same principle. In 1819 Cagniard de la Tour invented the siren, a much superior instrument, but incapable of giving very exact results, notwithstanding the simplicity of its mechanism. The same remark may be made of the toothed wheel invented by Savart in 1830.

A most important step in advance was made in 1834 by Henri Scheibler, of Crefeld, who in that year invented his tonometer, consisting of a series of 56 forks going from A (440) to its octave (880), the vibrations increasing regularly by differences of eight, any two adjacent forks thus giving four beats per second. Curiously enough, although Scheibler went to Paris and exhibited his tonometer there, he was unable to interest savants in his discovery; and it was not until the London exhibition of 1862 that the attention of physicists and musicians was directed to the value of the instrument by Koenig. The apparatus in its new form contained 65 forks going from C_3 (512) to C_4 (1024).

Notwithstanding the great utility of this tonometer to the acoustician, it still left undetermined the absolute pitch of the fundamental note, and hence of the whole series. This problem of realizing a standard of pitch remained practically unsolved, even after the French Government in 1859 decreed that the standard should be A = 870 v. s., at 15° C. The standard then constructed by Lissajous was found, in 1880, to be too high by $\frac{9}{10}$ of a vibration. The standard employed since 1880 by Koenig is C = 512 v. s. at 20°. The acoustical standard before that date was in reality 512.35 at 20°. The problem of realizing a standard fork, which had given rise to much controversy among physicists, was finally solved in 1880 by Koenig, who in that year published his paper 'Recherches sur les vibrations d'un diapason normal.' In this paper Koenig describes how by means of a clock-fork (horloge à diapason comparateur) he established a standard fork, the error of which did not exceed $\frac{1}{6000}$ of a vibration. The clock-fork method enables us at the same time to determine readily the variations in the number of vibrations due to a rise or fall of temperature. Having established in this way an absolute standard of C_3 = 512 v. s. at 20° C., Koenig commenced the construction of a universal tonometer based thereon, a colossal undertaking which he finished in 1897, after working a score of years. This tonometer, which has a range from 32 to 180,000 v. s., consists of the following:

1. 4 forks giving vibrations from 32 to 128, with differences at first of $\frac{1}{2}$ v. s. and afterwards of 1 v. s.

2. 132 large forks, tuned to give (without the sliders) the 127 harmonics of C_1, C_2, C_3, C_4, C_5, C_6, being in duplicate.

Each fork can be lowered, by means of sliders, to unison with the fork next below.

The differences immediately obtainable by sliders are:

1 v. d. between C_1 and C_3; 2 v. d. between C_3 and C_5; 4 v. d. between C_5 and C_7.

3. 40 resonators to reinforce forks of 2.

4. One large resonator of diameter 0.48 m. and of length varying from 0.30 m. to 2.30 m.

5. 18 forks for notes from C_7 to F_9.

6. 15 forks for notes from Sol_9 to 180,000 v. s.

Under the head of pitch come two very difficult questions relating to the audibility of very low or very high sounds. With regard to the former Helmholtz has shown that if the vibrations are very slow and do not follow the pendular law (the fundamental being thus accompanied by a series of harmonics), the fundamental may be quite inaudible, whilst the harmonic is heard distinctly. In such a case the harmonic is often mistaken for the fundamental. On the other hand, if we employ large tuning forks, vibrating rods, or the wave siren, for the purpose of obtaining pendular vibrations, we are still met with the difficulty of determining accurately the limits of audibility, owing to the fact that it not only depends on the intensity of the vibrations, but varies from one observer to another. In general it may be stated that it requires from 60 to 80 v. s. to produce a sound perfectly continuous and possessing a musical character. In using very powerful high forks to produce beats, which were gradually diminished in number, Koenig found that the sensation of a continuous low sound ceased when their number did not exceed 26.

As to the high notes above $C_7 = 8,192$, the amplitudes of the vibrations are generally so small that the ordinary methods no longer serve to determine the pitch. For this reason it was at first the practice to tune forks above C_7 by means of the ear. The high forks constructed by Marloye and presented to the Academy of Sciences at Paris, in 1848, by Depretz, were constructed in this way. In 1858, however, Koenig showed that even in the upper half of the octave $C_6 - C_7$, the best musicians ceased to judge the intervals accurately, a fact which seemed to show that it was extremely unlikely that forks giving notes two octaves higher could be tuned accurately by the ear. For this reason Koenig effected the tuning of very high forks by means of the sounds resulting from their beats. The first series of forks tuned in this way were made by Koenig in 1876. A set of similar forks constructed about the same time by Preyer, and going, as he alleged, as high as E_{10} were shown by Melde, in 1894, to be greatly out of tune, the intervals being wrong by as much as a third, and even an octave. In 1897, Melde's results were confirmed by Stumpf and Meyer.

In 1899 Koenig published his researches on very high notes. In this memoir, after showing the exactness of the tuning attained by the sounds of beats in forks between C_7 and F_9, he proceeds to state that, by means of Kundt's method of using light powders, he had constructed a series of high forks accurately tuned and proceeding according to the intervals of the perfect (major) scale, from C_7 to the enormous pitch of 180,000 v. s., and that without reaching a limit to the number of such vibrations.

As to the audibility of these high forks, it has been remarked by Koenig that those between C_7 and C_9 are generally audible, whilst C_{10} and those above are entirely inaudible. He further remarks that the limit of audibility, which thus lies between C_9 and C_{10}, largely depends, as in the case of low sounds, on the intensity, and varies with the individual.

INTENSITY.

With regard to the question of intensity of sound, it is only necessary to say that there exists here a great lacuna in our acoustical knowledge, as we do not yet possess a means of measuring the physiological intensity of sound.

TIMBRE.

To Helmholtz belongs the credit of first elucidating the question of timbre by showing that the timbre of a sound depends upon the number and intensity of the harmonics accompany the fundamental. The question of timbre is thus intimately connected with the study of the phenomena produced by the coexistence of two or more sounds. With regard to such phenomena, it was stated by Helmholtz that when two notes of different pitch are sounded together, they give rise to two other sounds, the pitch of which is measured, the one by the difference, and the other by the sum of the vibrations of the two primary sounds. Further, that these resultant sounds are not due to beats.

These propositions of Helmholtz are controverted by Koenig, who, on the contrary has proved that the sounds actually heard accompanying two primary sounds are always due to beats. Koenig asserts, moreover, that the sounds referred to by Helmholtz, even if we could prove that they had a real existence, would always be inaudible, and therefore without effect on the acoustical phenomena. He further establishes the curious fact that even interruptions of a sound give rise to another sound.

As to timbre, Helmholtz's theory was that it depended solely on the number and relative intensities of the harmonics which accompany the fundamental, and that it is not affected in any degree by differences in the phases of these components. This latter proposition is combated by Koenig who holds that differences of phase as regards harmonics exercise a very important influence on the timbre of a sound, so that according to him timbre depends on the number, relative intensities and differences of phase of the harmonics which accompany the fundamental. Koenig's experiments on this disputed point were performed with his large wave-siren. Even this wider definition of timbre is, however, according to Koenig's most recent view and experiments, insufficient, as not being applicable to certain classes of timbres—for example, those produced by most musical instruments, especially stringed instruments. In these cases the fundamental is accompanied not only by harmonics, but also by other sounds which are not harmonic, the superposition of which produces series of waves which change their form successively. These wave forms have been investigated by Koenig in a paper, 'Sur les timbres à ondes de formes variables,' in which he determines the conditions under which such timbres may be considered musical, and concludes that in these cases the fundamental is accompanied by harmonics which continually change their relative intensities and their phase-differences.

In conclusion I may state that, according to Koenig, the fact that differences of phase amongst harmonics produce differences of timbre is explained for the first time by his recent discovery that the intensity of a sound can be increased by the addition of another sound, when the maxima of intensity in the vibrations in the two cases correspond more or less exactly, and that several sounds produced together may reinforce a sound of lower pitch than any of them. For example with the same six primary sounds, by changing their phases only, he produces not only timbres differing in intensity and in richness, but timbres in which, at one time, the octave (2) and at another time the fifth above (3) are heard. The difference between these two timbres is, indeed, so great that when heard in succession, there appears to be an interval of a fifth between them, although their fundamentals are exactly the same. These experiments may be said to be the last on this difficult subject in the years of the century which has just closed.

JAMES LOUDON.

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